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ANCHORING FOR A PRE-TENSIONED AND/OR LOADED TENSION MEMBER AND ANCHOR SLEEVE
[Verankerung für ein vorgespanntes und/oder belastetes Zugelement und Ankerbüchse]

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Description /1[*]

The subject matter of the present invention is an anchoring for a pre-tensioned or loaded tension member of a fiber composite material and an anchor sleeve.

The global trend shows the increasing importance of high-strength, unidirectional fiber composite materials as nonmetallic, pre-tensioned tension members (e.g. oblique cables, prestressing members, pressure-grouted anchors) and loaded tension members (e.g., suspensions, supports against tractive forces) in construction.

Compared to metallic tension members, tension members of fiber composite materials possess superior corrosion resistance with respect to weathering and are lighter in weight.

Tension members of fiber composite material generally comprise fibers arranged parallel to one another along the length of the tension members, for example embedded in a reaction resin matrix. Typical fibers are made with carbon, inorganic glass, or aramid. Epoxy resins, unsaturated polyester resins, vinyl ester resins, as well as polymers with or without fillers are used for the matrix.

The fibers possess both elastic and brittle material behavior. The matrix of fiber composite evens out the forces and the transfer of force from broken to intact fibers. The matrix also reduces the sensitivity of the fibers to transverse pressure.

[*] Number in the margin indicates pagination in the foreign text.

The production of tension members of fiber composite material /2 is accomplished by pultrusion. Wires and rods of round cross section as well as braids of individual fibers are generally produced. A tension element can be made of a plurality of tension members and a sheathing to protect against the entry of water and UV radiation.

Tension members of nonmetallic fiber composite material are mechanically anisotropic. Excellent material properties, such as high tensile strength and rigidity in the longitudinal direction are contrasted to far less strength in the transverse direction.

In the anchoring for a tension member of fiber composite material, multiple stresses occur in the tension member. The transfer of force from the tension member through the anchor body to the anchor sleeve occurs via shear stress and transverse tension. Due to the sensitivity to transverse pressure on the part of the tension members, the anchoring experiences a reduction in bearing capacity, compared to the free stretch outside the anchoring. The ratio of the bearing capacity of the tension member in the anchoring to the bearing capacity of the tension member in the free stretch is called the efficiency of the anchoring.

Various anchorings for tension members of nonmetallic fiber composite material have been developed in the past. A distinction is made among clamping plate anchorings, cylindrical, and conical cast anchorings.

In clamping plate anchorings, the tractive force is transferred via friction bond tensions from the tension member to the clamping plates. Considering the sensitivity to transverse pressure of the tension member of nonmetallic fiber composite material, the compression force of the clamping plates is adjusted such that the compression force in the load-bearing region of the anchoring is less than in the region remove from the load. This produces a more even /3
transfer of force and, thus, a higher degree of anchoring efficiency. Relative shifts between tension member and clamping plates in the case of clamping plate anchorings can lead to failure of the anchoring under dynamic stress. Due to the complex anchoring technique and the danger of premature failure under dynamic load, it may be expected that clamp anchorings will not be widely used.

In cylindrical cast anchorings, higher shear stress occur in the load-bearing region of the anchoring between tension member and casting compound than in the region remote from the load.

The design of a cylindrical cast anchoring as a clamping piece anchoring is described by Rostasy in the journal Bauingenieur, vol. 73, p. 301. With this anchoring, the tension member of fiber composite material is anchored in a steel sleeve with a cast material by adhesive bond and wedges. This anchoring causes a sharp decrease in the tractive force in the region of the wedge anchoring, since higher shear stresss are transferred by the transverse pressure. However, a uniform transmission of the tractive force from the

tension member into the anchoring with the clamping piece anchoring is not possible, despite its complex design.

The transverse pressure in conical cast anchorings, in which the smallest cross-sectional area of the cavity is near the load-bearing region and, thus, the imaginary point of the cone is arranged near the load-bearing region, increases the shear stress that can be accommodated between the tension member and the anchor body, but it can also lead to premature destruction of the tension member in the anchoring, since fiber composite materials are sensitive to transverse pressure. /4

WO 95/29308, on which prior art the present invention is based, describes a conical cast anchoring for nonmetallic tension members of fiber composite material, having an anchor sleeve with a conical cavity, whose smallest cross-sectional area is near the load-bearing region and the largest cross-sectional area is remote from the load, and an anchor body of a casting compound arranged between anchor sleeve and tension member. Along its longitudinal extent, the casting compound of the anchor body has different moduli of elasticity. At the entry of the tension member into the anchoring, the modulus of elasticity of the casting compound is low and it increases continuously toward the part of the anchoring remote from the load. With this graduated design of the anchor body, a more uniform transfer of force from the tension member to the anchor sleeve is

intended to be achieved. The production of a cast material in several layers is a costly process.

The object of the present invention is to create an anchoring for one or more tension members of nonmetallic fiber composite material that is simple to produce and allows a more uniform transfer of force along the tension member to the anchor sleeve and that makes it possible to stand up to higher dynamic loads.

The anchoring of this invention for a pre-tensioned and/or loaded tension member, particularly of a nonmetallic fiber composite material, whereby the tractive force of the tension member can be transferred via an anchor body of strengthened, in particular hardened, cast material, to an anchor sleeve, which has varying /5
cross-sectional areas normal to the axis of the tension member, essentially comprises a design in which the inner wall of the anchor sleeve has a contoured shape and the cross-sectional area of the anchor body normal to the axis of the tension member is greater in the load-bearing region of the anchor sleeve, in particular has a maximum value, and is smaller in the region remote from the load.

Fiber composite materials generally comprise nonmetallic fibers, such as glass, carbon, aramid, or other plastics, that possess a particularly high corrosion resistance with respect to exposure to the atmosphere. In this way, tension elements with such an anchoring, as used for construction, for example bridges and buildings, but also earth and rock anchoring, have a particularly high durability. The

nonmetallic fiber composite materials can possess a particularly high tensile strength, but their strength under transverse stresses is especially low. To allow for this, the tension members can be fixed in an anchor sleeve with a material that can be inserted into the anchor sleeve in a state capable of flow, through which no forces transverse to the longitudinal extension of the tension members can be applied. If the cross-sectional area of the anchor body normal to the axis of the tension member in the load-bearing region of the anchor sleeve is greater and, in particular, if it has a maximum value, and is smaller in the region remote from the load, then the anchor body widens in the direction of traction. Thus, geometric anchoring of the anchor body with smooth walls in the anchor sleeve could not occur. To prevent the anchor body from being pulled out of the anchor sleeve, the inner wall of the anchor sleeve is made with a contoured shape. In this way, the forces that are exerted by the /6
tension element on the anchor sleeve are more uniformly distributed. Particularly in the region of greatest load of the tension element, the anchor body is given a greater mass, so that the forces that are exerted on the latter can be better distributed.

If the contoured shapes are formed by ribs, beads, indentations, steps, recesses, or bulges, then various designs of the contoured shape can achieve secure anchoring, mechanical anchoring of the anchor body in the anchor sleeve being assured.

If at least two tension members are anchored in the anchor body, then a particularly large surface can be present for fixing the tension members in the anchor body.

If the anchor sleeve has at least two anchor bodies for accommodating the tension members, then a particularly high degree of mechanical anchoring of the tension members in the anchor sleeve can be achieved.

If the end of the anchor sleeve remote from the load comprises a plate and if the latter has at least one load-bearing element that is parallel, in particular parallelly oriented, to the tension member(s), then a particularly force-absorbing anchor sleeve can be obtained.

If the tensile strength of the strengthened, in particular hardened, cast material of the anchor body is less, in particular considerably less, than the compressive strength, then crack formation can occur in the anchor body, resulting in struts, which transfer the forces to the anchor sleeve.

If the inner wall of the anchor sleeve has a coating that /7 prevents connection with the anchor body, so that sliding of the anchor body in the anchor sleeve can be achieved, and the anchor sleeve exerts no tension on the anchor body, struts can again be formed.

If the wall thickness in the load-bearing region of the anchor sleeve is less than in the region remote from the load and if the

anchor sleeve is stepped, so that during transmission of the tractive force from the tension member via the anchor body to the anchor sleeve the stress on the tension member as it enters the anchor body is reduced by the yieldingness in the load-bearing region of the anchor sleeve, then particularly favorable compensation of the forces between the anchor sleeve and the anchor body and thus of the stress on the tension members is provided.

If the anchor body is made cylindrical in the region remote from the load, then a particularly long anchor body can be obtained, which is particularly favorable for making adjustments.

If the strengthened, in particular hardened, casting material is capable of being under load by a tractive force, in particular a variable one, in such a way that it experiences creep, then a more uniform transfer of force from the tension member via the cast material to the anchor sleeve can be achieved by permanent deformation of the cast material.

If the strengthened, in particular hardened, cast material is capable of being under load at elevated temperature by a tractive force, in particular a variable one, over a prolonged period of time, then a more uniform transmission of forces from the tension member via the casting compound, which has been subjected to a permanent deformation, to the anchor sleeve can be achieved. /8

The anchor sleeve of this invention with at least one cavity with a wall, said cavity being open at at least one end, whereby the

cross-sectional area of the cavity varies normal to its longitudinal direction, essentially comprises a design in which the wall has a contoured shape, which extends transverse, in particular normal, to the longitudinal direction of the cavity. Due to the varying cross-sectional area of the cavity, anchor sleeves having a conical surface can be arranged in such a way that the greatest cross section is near the load, making possible a particularly favorable absorption of the forces, since the greatest force absorption is at the beginning of the anchor sleeve, i.e. in the load-bearing region, while the least forces are transferred in the region of the anchor sleeve remote from the load. Clearly, there is a prejudice against such an arrangement of the cavity, since there is a tendency to achieve large-surfaced mechanical anchoring of a cast body in the anchor sleeve. If the wall has a contoured shape, which extends transverse, in particular normal, to the longitudinal direction of the cavity, then this contoured shape can produce a mechanical anchoring of the tension member via the casting compound.

If the contoured shapes of the wall extend into the cavity, then it is a particularly simple matter to fill the cavity with the flowable mass that is strengthened or hardened.

If the anchor sleeve is closed at one end, said end having smaller cross-sectional surfaces of the cavity, then the anchor sleeve is provided with particularly high strength, allowing smaller dimensions of the latter for the same force absorption. /9

If a plurality of cavities are provided, in particular with axes arranged parallel to one another, then especially large surfaces can be achieved for force transfer between the anchor body and the anchor sleeve.

If the cavities are made rotationally symmetric, then a particularly symmetrical force transfer is possible between the anchor body and the anchor sleeve.

The invention will be explained in greater detail below with reference to the drawings.

The figures show:

Figure 1: a longitudinal section of an anchoring in accordance with this invention,

Figure 2: a cross section along line II-II in Fig. 1,

Figure 3: a longitudinal section of a second embodiment of the anchoring in accordance with this invention,

Figure 4: a longitudinal section of a third embodiment of the anchoring in accordance with this invention,

Figure 5: a longitudinal section of a fourth embodiment of the anchoring in accordance with this invention,

Figure 6: a longitudinal section of a fifth embodiment of the anchoring in accordance with this invention,

Figure 7: a cross section along the line VII-VII in Fig. 6, /10

Figure 8: a longitudinal section of a sixth embodiment of the anchoring in accordance with this invention,

Figure 9: a cross section along the line IX-IX in Fig. 8,

Figure 10: a longitudinal section of a seventh embodiment of the anchoring in accordance with this invention, and

Figure 11: a cross section along the line XI-XI in Fig. 10.

A longitudinal section through a first embodiment of an anchoring in accordance with this invention is shown in Fig. 1.

Anchor sleeve 4 consists of steel and was produced with milling tools. However, sleeves of fiber composite materials can also be used. The anchoring shown in Fig. 1 is connected on the outside by a thread 49, using a ring nut 50.

Anchor body 6 is made of a hardened cast material 3. Examples of the cast material are epoxy resins, Dywipox (registered trademark of the company Dyckerhoff Systems International, Munich). Good joining properties between tension member 2 and anchor body 6 is required, in order to transfer the tractive force from tension element 1 with only one tension member 2 to anchor body 6. The tension element is made using carbon fibers having a diameter of 10 μm, joined together with epoxy resins. Other possible fibers that can be used are those of inorganic glass, aramid, or the like. Such tension members can be purchased, for example, from the firm Stesalit AG (Switzerland), Nedri Spanstaal BV (Netherlands), and Toray Industries Inc. (Japan).

Anchor body 6 of the anchoring shown in figure 1 has the form /11 of a truncated cone. In a cross section of load-bearing region 41 of the anchoring in Fig. 2, anchor body 6 has a greater cross-sectional area then in a cross section in region 42 of the anchoring remote from the load. With this geometric shape of anchor body 6, the bond stresses between tension member 2 and anchor body 6 are more evenly distributed than in a cylindrical or conical cast anchoring of the conventional type.

Anchor sleeve 4 serves as a form for making anchor body 6. Inner wall 44 of anchor sleeve 4 must be made in such a way that, when tension member 2 is under load, anchor body 6 is not pulled out of anchor sleeve 4. With suitable machining of inner wall 44 of anchor sleeve 4, the surface has a contoured shape 45.

Figure 3 shows a longitudinal section of the anchoring in accordance with this invention as a modified embodiment of the one in Fig. 1. Inner wall 44 of anchor sleeve 4 is provided with steps 46, on which anchor body 6 rests when tension member 2 is under load. If steps 46 are given the proper shape with respect to their spacing and inclination to tension member 2, the shear stress along tension member 2 can be influenced. A plurality of truncated cones can be produced, which have a smaller cross section near the load than remote from the load, so that a mechanical clamping of the tension element in the anchor body is achieved.

Figure 4 shows a longitudinal section of a modified embodiment of the inventive anchoring in Fig. 1. The surface of anchor body 6 normal to tension member 2 increases continuously in the load-bearing region of anchoring 41 and is constant in region 42 remote from the load. Thus, this anchoring is a development of the known /12 cylindrical cast anchoring. The increase in shear stress in load-bearing region 41 of the anchoring occurring in the case of cylindrical anchorings is eliminated by the expansion of anchor body 6, as seen in Fig. 4. Anchor sleeve 4 of the anchoring shown in figure 4 has a contoured shape 45 on inner wall 44 and delivers the force to an anchor plate 60.

Figure 5 shows a longitudinal section of a modified embodiment of the inventive anchoring in Fig. 1. Inner wall 44 of anchor sleeve 4 has only one step 46, which accepts a considerable portion of the force. The remainder of the force is transferred via anchor body 6 to contoured shape 45 of inner wall 44 of anchor sleeve 4.

Figure 6 shows a longitudinal section of a modified embodiment of the inventive anchoring in Fig. 1. Tension element 1 comprises three tension members 2 of fiber composite material, which are embedded in a conical anchor body 6. The wall thickness, d, in load-bearing region 41 of anchor sleeve 4 in this anchoring is so thin as to affect the shear stress between tension member 2 and anchor body 6, due to the yieldingness in anchor sleeve 4. A section along line

VII-VII, through load-bearing region 41 of the anchoring, is shown in Fig. 7.

Figure 8 shows a longitudinal section of a modified embodiment of the inventive anchoring in Fig. 1. Tension element 1 comprises three tension members 2 of fiber composite material. Each tension member 2 is embedded in a conical anchor body 6. In the exemplary /13
embodiment of Fig. 8, anchor bodies 6 are arranged parallel to the axis of tension element 1. A section along the line IX-IX, through the anchoring, is shown in Fig. 9.

Figure 10 shows a longitudinal section of a modified embodiment of the inventive anchoring in Fig. 1. Tension element 1 comprises six tension members 2 of fiber composite material. At the end remote from the load, anchor sleeve 4 has a plate 70, which has a load-bearing element 80. Tension members 2 transfer the force via bond stresses to anchor body 6, which becomes wider in load-bearing region 41. Anchor body 6 transfers the tensile force to inner wall 44 and load-bearing element 80, which extends into anchor body 6 in the manner of a mandrel. A section along line XI-XI through the anchoring is shown in Fig. 11.

By utilizing nonlinear effects, such as the creep behavior of cast material 3, particularly at temperatures above room temperature, an additional evening of the shear stresses along tension member 2 can be achieved. Due to the shaping of anchor body 6 in combination with cast material 3, which has different strength values under

compressive and tensile stress, the stress present in the anchoring can be selectively influenced.

In order to achieve purely mechanical anchoring, the wall can be provided with a release agent, such as silicone oil, before the liquid cast material is poured into the anchor sleeve, so that no adhesive bond is produced.

The shape of anchor body 6 is not limited to the shapes /14 presented in Figs. 1 to 11. In particular, anchoring bodies 6 could be made that are not circular in cross section, making possible transmission of the tractive force with shear stresses that are uniformly distributed along tension member 2.

Claims

1. Anchoring for a pre-tensioned and/or loaded tension member (1, 2) of a fiber composite material, a nonmetallic one, whereby the tractive force of the tension member can be transferred via an anchor body (6) of strengthened, in particular hardened, cast material (3) to an anchor sleeve (4), which has varying cross-sectional areas normal to the axis of the tension member, characterized in that the inner wall (44) of the anchor sleeve (4) has a contoured shape (45) and that the cross-sectional area of the anchor body (6) normal to the axis of the tension member (2) is greater in the load-bearing region (41) of the anchor sleeve (4), having in particular a maximum value, and smaller in the region (42) remote from the load.

2. An anchoring as recited in Claim 1, characterized in that the contoured shape (45) is formed by ribs, beads, indentations, steps (46), recesses, or bulges.

3. An anchoring as recited in Claim 1 or 2, characterized in that at least two tension members (2) are anchored in the anchor body (6).

4. An anchoring as recited in Claim 1, 2, or 3, characterized in that the anchor sleeve (4) has at least two anchor bodies (6) for receiving the tension members (2).

5. An anchoring as recited in one of the Claims 1 through 4, characterized in that the end (42) of the anchor sleeve (4) remote

from the load comprises a plate (70) and that said plate (70) has at least one load load-bearing element (80) parallel, in particular oriented parallel, to the tension member(s) (2). /16

6. An anchoring as recited in one of the Claims 1 through 5, characterized in that the tensile strength of the strengthened, in particular hardened, cast material (3) of the anchor body (6) is less, in particular considerably less, than the compressive strength.

7. An anchoring as recited in one of the Claims 1 through 6, characterized in that the inner wall (44) of the anchor sleeve (4) has a coating that prevents adhesive bonding of the anchor body (6) to the anchor sleeve (4).

8. An anchoring as recited in one of the Claims 1 through 7, characterized in that the wall thickness in the load-bearing region (41) of the anchor sleeve (4) is less than in the region (42) remote from the load and that the anchor sleeve (4) is stepped in such a way that during transmission of the tractive force from the tension member (2) via the anchor body (6) to the anchor sleeve (4), the stress on the tension member (2) as it enters the anchor body (6) is reduced by the yieldingness in the load-bearing region (41) of the anchor sleeve (4).

9. An anchoring as recited in one of the Claims 1 through 8, characterized in that the anchor body (6) in the region (42) of the anchor sleeve (4) remote from the load is made cylindrical.

10. An anchoring as recited in one of the Claims 1 through 9, characterized in that the strengthened, in particular hardened, cast material (3) is capable of being under a load by a tractive force, in particular a variable one, in such a way that it experiences creep.

11. An anchoring as recited in one of the Claims 1 through 10, /17 characterized in that at elevated temperatures the strengthened, in particular hardened, cast material (3) is capable of being under load by a tractive force, in particular a variable one, over a prolonged period of time, in such a way that it experiences creep.

12. An anchor sleeve (4), in particular for an anchoring as recited in one of the Claims 1 through 11, with at least one cavity with a wall (44), said wall being open at at least one end, whereby the cross-sectional area of the cavity varies normal to its longitudinal direction, characterized in that the inner wall (44) has a contoured shape (45), which extends transverse, in particular normal, to the longitudinal direction of the cavity.

13. An anchor sleeve (4) as recited in Claim 12, characterized in that the contoured form (45) of the inner wall (44) extends into the cavity.

14. An anchor sleeve (4) as recited in Claim 12 or 13, characterized in that the anchor sleeve (4) is closed at one end, said end having cross-sectional surfaces of the cavity.

15. An anchor sleeve (4) as recited in Claim 12, 13, or 14, characterized in that a plurality of cavities are provided, in particular with axes arranged parallel to one another.

16. An anchor sleeve (4) as recited in one of the Claims 12 through 15, characterized in that the cavity(cavities) is/are made rotationally symmetrical.

Fig. 1

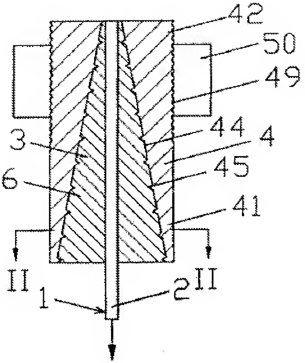

Fig. 2

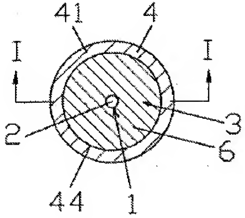

Fig. 3

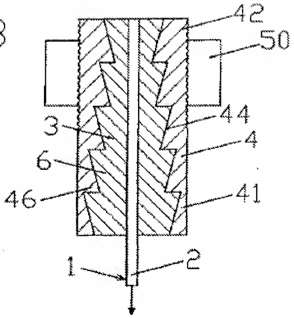

Fig. 4

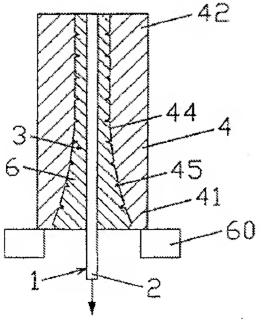

Fig. 5

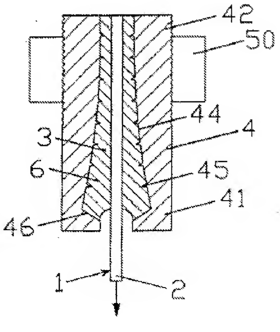

Fig. 6

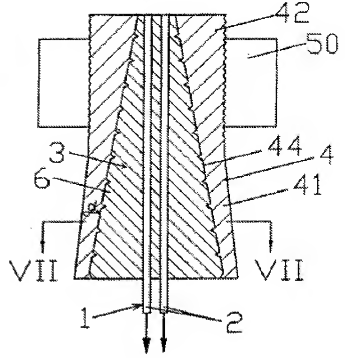

Fig. 7

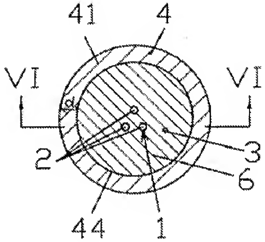

Fig. 8

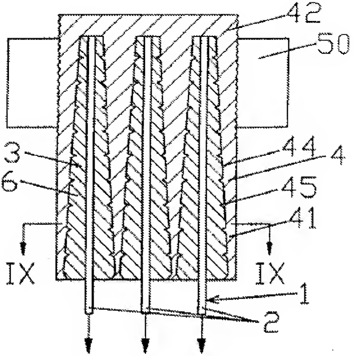

Fig. 9

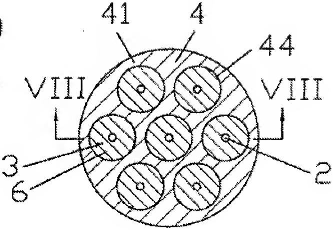

Fig. 10

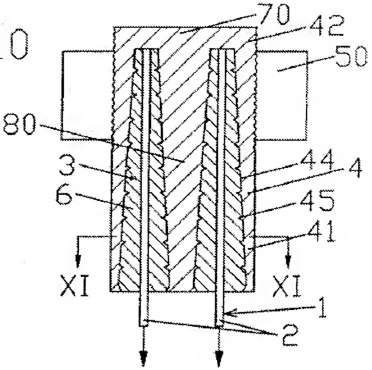

Fig. 11